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Recent years have witnessed a great expansion in the use of the microscope in industry as well as in science with the result that routine microscopy, which was formerly done by self-selected specialists, must now be entrusted to technicians. The visual acuity of technicians, especially in such routine work as counting objects or searching for casts, tubercle bacilli and other microscopic objects, thus becomes a matter of prime importance, not only because of its effects on reliability and accuracy, but particularly because the maintenance of visual acuity in persons with good vision is wholly dependent on freedom from eyestrain, fatigue and toxins.

The physiologic optics of microscopy are rendered exceedingly complex by the multiplicity of fine muscular adjustments, intricate nerve mechanisms and selective action of diverse stimuli on the delicate nerve end structure of the retina. All these are involved in the impairment of visual acuity and the production of such symptoms of fatigue and strain as headache, somnolence, muscular pain, blepharospasm, flicker dizziness and disturbances of accommodation and vision, such as blurring, spots and color sensations. When microscopists with such symptoms are seen by ophthalmologists, some slight muscular deficiency or error of refraction is generally found, which, when corrected, often leads to respite or amelioration but very seldom to a cure. In our experience, even a slight muscular trouble permanently restricts the capacity of a microscopist to do routine work with dependable visual acuity. On the other hand, refractive error patients get along far more comfortably and reliably. In this connection, it is of interest to note that no technician who began with tested emmetropic eyes has been encountered by

* From the Prudential Longevity Service.

us who managed to continue routine microscopy longer than two years without finding it necessary to be fitted with glasses.

In an attempt to get a closer insight into the causative factors of deterioration of visual acuity and other symptoms of strain and fatigue incident to microscopy, three technicians, G. S., J. H. and E. W., were kept under continuous observation for more than two years. All were healthy young adults. E. W. and J. H. had tested normal vision; G. S. wore a correction for astigmatism.

Their work with monocular microscopes proved definitely that suppression of the image in the "off eye" is invariably accompanied by effort and strain, no matter how practiced the microscopist may be. Their experience has demonstrated also a very close incidence between the time spent in looking through the microscope and the occurrence and character of the complaints. Thus, blurred vision was never experienced except in connection with overwork. Experiments made with high and low magnifications showed a close relationship between high magnifications and eyestrain, and the association of intensity of light with loss of acuity and other symptoms became also plainly evident. Thus, a glare, or too much light through the microscope induces symptoms of irritation, such as blinking, blepharospasm and lacrimation, while insufficient light results in quick fatigue and diminished acuity, due, in part at least, to the effects on accommodation.

Our observations may be summarized by the statement that many factors contribute to the production of lessened acuity, discomforts and other signs of fatigue and strain connected with microscopy. These factors occur either singly or in combination with other factors, and while manifesting a decided tendency to vary with the individual, are not always similarly operative as regards either cause or effects, even in the same individual.

The only constant factor is posture, which induces different effects according to the position assumed by a microscopist; this, in turn, is influenced by the type of spectacle or eyeglass frame worn, at times also by an existing visual defect or other anatomic peculiarity. Certainly, the maintenance of a fixed position of the head and neck always involves strain with consequent discomfort and fatigue, and this became plainly apparent when a trial was made of binocular microscopes.

Thus, all three technicians preferred to return to the monocular, finding that the greater rigidity and fixation of the head and neck, and possibly also of the ocular musculature, required by binocular microscopes caused discomforts for which the visual relief afforded by them did not compensate. In fact, it soon becomes plain that the monocular microscope allows more elasticity of position and greater ability to shift than binocular microscopes.

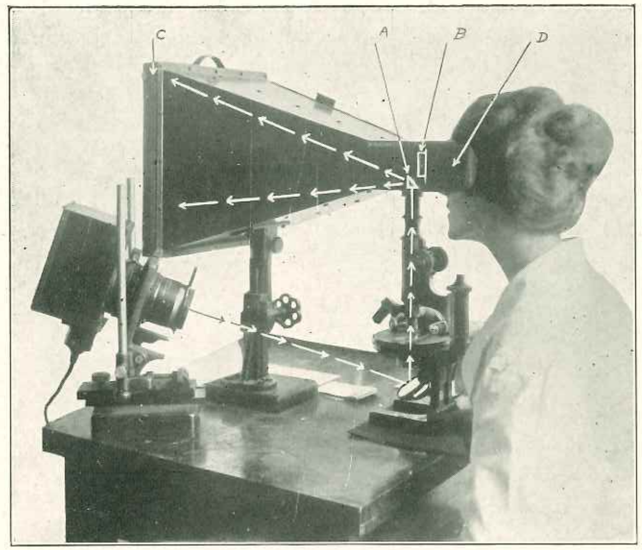

Fig. 1.—Euscope arranged for microscopy. Arrows indicate path of light: A, total reflecting prism; B, mount for sphero prisms or other magnifiers; C, screen or photographic plate or paper, and D, shield for side and extraneous light.

CONSTRUCTION OF THE EUSCOPE

Attempts to aid and improve microscopy led to the construction of the euscope (*εὖ*, well or comfortably; *σκοπεῖν*, to see), which, with binocular single vision, provides enlarged images of stereo effect in conjunction with diminished light irritation to the nerve end organs of the retina, and permits natural, easy posture with complete relaxation and freedom of the head, neck and ocular muscles.

From Figure 1 it will be seen that the euscope consists of an adjustable stand supporting a camera or viewing

chamber, having on its floor, near the smaller end, an aperture to receive the eyepiece of the microscope. In this is placed the removable mount of a total reflecting prism, which bends the ray of light emerging from the microscope at a right angle in such a way that the microscopic image is deflected to the screen at the larger end of the eusope. From this it will be seen that euscopy is done by projection, with all its attendant facilities and advantages.

The viewing chamber, or camera, is light tight and screened from side and extraneous light by a conforming shield fitted to the ocular or smaller end, which insures comfortable projection in bright daylight. A lens plate or diaphragm, placed between the ocular end and the prism aperture, carries a pair of spheroprisms or a strip of reading glass of proper focus, which has the advantage of eliminating interpupillary adjustments. Either of these greatly enhances effectiveness by adding magnification, crispness and stereo effect.

The larger, or screen end is arranged to allow easy removal of the screen for the projection of large images or replacement of the screen by a photographic plate or paper holder. Experiments with different screen materials in the effort to get a screen with hard, white matte surface, as free from graininess as possible, showed that screens made of calcium tungstate or of green zinc oxid or of titanium oxid are satisfactory and durable, the zinc oxid having the finest grain.

Any type of efficient lamp will satisfy illumination requirements. For critical illumination, however, and particularly for photography, a homogeneous source of light, such as is always preferred for projection, will give very much better results than any other. Of these, the new ribbon filament lamp or the older tungsarc are recommended. New lamps are in process of development which will amplify illumination, but the lamps named above will be found to satisfy every reasonable requirement, except distant projection, especially if provided with a condensing lens having a cartesian surface.

The only change in one's accustomed microscopic technic required by the euscope consists merely in manipulating the object slide to conform with the true position of the object, instead of the reverse, as when seen with the unaided microscope. This will be found advantageous and also makes the monocular microscope available for chemical microscopy. Another technical

point to be noted is the adjustment of the height of the euscope so that its prism rests as close as possible to the top lens of the eyepiece of the microscope.

For routine work, a 150 millimeter square screen conveniently placed at a distance of 200 mm. from the reflecting surface of the prism is satisfactory. Seen through the strip of reading glass, the visual field has then the apparent size of a full page magazine illustration, differing somewhat with the type of objective and eyepiece employed. The image appears crisp with three

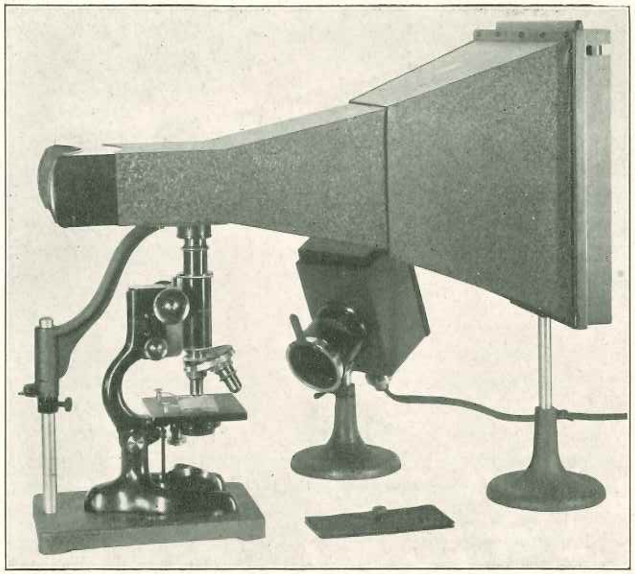

Fig. 2.—Simplified euscope, extended, with accessories.

dimensional effect, and corresponds with the normal projection of standard microscopes. It is to be noted, however, that any spherical aberration of the objective is accentuated, as is to be expected in projection. Any possible combination of eyepiece and objective may be used. With objectives less than 16 mm., a larger field is secured with the concave mirror of the microscope, or by lowering the condenser and using the plane mirror, which should be regularly employed with objectives of higher power. The enlarged stereo-like images thus

possible with binocular single vision are seen without effort in a natural, easy sitting position, permitting perfect freedom of play of the head, neck, back and ocular musculature. By viewing a reflection on a screen instead of looking directly at the light source as one does with the unaided microscope, irritation of the rods and cones of the retina, with consequent fag of the visual purple, is reduced to a minimum, and more of the retina is brought into play.

Eyeglasses or spectacle frames of any type may be worn with perfect comfort and offer no handicap. This is true whatever the correction needed by the individual microscopist, bifocal lenses being as comfortably worn as simpler ones. Thus, routine microscopy is brought, as regards comfort and strain, to a level with ordinary clerical work, and the ease and certainty with which structural details are seen appreciably increase the efficiency and capacity of the microscopist. As evidence of this is the experience that during the four years in which euscopes have been used in the Prudential laboratory, not a single complaint referring to fatigue or strain symptoms has been heard.

OTHER USES OF THE INSTRUMENT

For teaching and demonstration work, the euscope can be used in a dark room as a simple projection apparatus by removing the screen and employing a sufficiently intense light. In semilighted rooms, the opaque screen may be replaced by a transparent screen of thin white Japanese silk or a thin plate of glass with a finely ground surface. A transparent screen of particularly fine grain for this purpose may be prepared with an unexposed photographic plate.[1] Either method permits the demonstration of microscopic specimens with any combination of eyepiece and objective desired by the instructor, who can remain comfortably seated while manipulating the microscope in his normal, accustomed manner. Microscopic objects have in this way

1. A clean plate slightly larger than the desired size should be taken in order to trim defective or injured edges. It should be fixed in hypo, washed and dried, and stock solutions A and B should be prepared, A consisting of 10 per cent. barium chlorid and B of 10 per cent. chemically pure sulphuric acid. Solutions A and B are each diluted 200 times, and the dilutions are placed in separate trays. The plate should be soaked in A tray five minutes, washed and rinsed carefully with water, and then soaked in B tray five minutes. This should be repeated until the density is about one-half what is wanted. Fineness and evenness of grain depend on manipulative care, particularly in washing and rinsing the plate when changing from one tray to another.

been demonstrated with the euscope continuously for hours at a time in well lighted exhibition halls. By varying the arrangement, instruction may be given students by means of the euscope with much saving of time and uncertainty.

Photomicography has possibilities of usefulness that have not yet been realized, largely because of the special skill and apparatus that have heretofore been required. The euscope, being a natural camera, makes photography practical for routine work, even in the hands of the inexperienced. Thus, at any time during the examination of a slide that may present some unusual or interesting feature that it is desired to record, one can simply replace the viewing screen by photographic plate or paper and expose it. No other accessory or manipulation is necessary than intercepting the beam of light between the lamp and the microscope mirror with a piece of cardboard, while withdrawing and replacing the slide of the plate holder. The construction of the euscope permits the use of either 4 by 5 or 8 by 10 inch plates or bromid papers for record photographs. In this way, blood counts may be made photographically with 16 or 8 millimeter objectives, which give a field large enough to include all of the 400 squares of the hemocytometer slide, and when made in this way, not only serve as records but also are obtained more accurately and less tediously.

For research work, the euscope offers possibilities, in addition to those mentioned, in connection with routine work and photography. The highest magnifying powers demand a close and exact approximation of the cornea of the observer to the top lens of the eyepiece, in conjunction with fine focusing, which is generally attended with disturbance of definition and difficulty of continuous study. With the euscope, however, objectives and eyepieces of the highest resolving powers can be employed just as conveniently and without more difficulty than those of lower power.

It need hardly be stated that the euscope does not increase the resolving power of the microscope, which now practically reaches the theoretical limit of attainment fixed by the wave length of light. The euscope, however, permits better utilization of the limit of resolution and also offers magnifications that have not been hitherto obtainable by direct vision. Thus, the limit of microscopic resolving power is attained with the com-

bination of 1.4 numerical aperture and 2 millimeter equivalent focus objective and 30 $\times$ compensating eyepiece, giving 2,700 magnifications. According to the formula:

$$\text{magnifications} = \frac{\text{projection distance}}{\text{focal length of objective}} \times \text{eyepiece magnifications}$$

It will be seen that by using the 400 millimeter screen distance of the euscope, 6,000 magnifications are reached. Adding the strip of reading glass, which is part of the euscope equipment, more than 10,000 magnifications are attained, and if a 6 $\times$ binocular stereoscopic magnifier is employed instead of the reading glass, more than 35,000 magnifications may be clearly and comfortably studied, and it is possible to more than double such magnifications wtih monocular magnifiers of higher power. In this way, minutiae, although resolved by the objective but which are so fine as to appear indeterminate because of the small angle of arc they subtend, are spread and may be seen much better. Thus in a recent study of the optical constants of fine crystals, a novice easily determined with the euscope extinction angles which an expert was unable to measure with the unaided petrographic microscope.

Euscopy is applicable to other optical instruments as well as to the microscope, and will be most appreciated when the heights of the table and the chair are so adjusted that, when he is seated in a natural and easy position, the eyes of the observer are on a level with the ocular end of the euscope.

In its later development, many technical problems needed solution before the euscope could be made generally available in the form seen in Figure 2, and I am happy to record my indebtedness for his interest and great technical knowledge to Mr. Max Poser of the Bausch and Lomb Optical Company of Rochester, N. Y., which has been entrusted with the construction of the euscope. The method of preparing the transparent screen is given through the courtesy of Dr. C. E. K. Mees, director of the research laboratory of the Eastman Kodak Company, and thanks for materials for experimenting with opaque screens are due Dr. Green of the New Jersey Zinc Company and Mr. M. R. Paul of the National Lead Company. To Messrs. Kroesen, Force, Porter and Prideaux of the Harrison Lamp Works of the General Electric Company and to Mr. Buttolph of the Cooper Hewitt Company, I am under obligations for their interest and cooperation in the experimental work connected with illumination.

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